Integrated Systems Health Engineering and Management
State-of-the-Art

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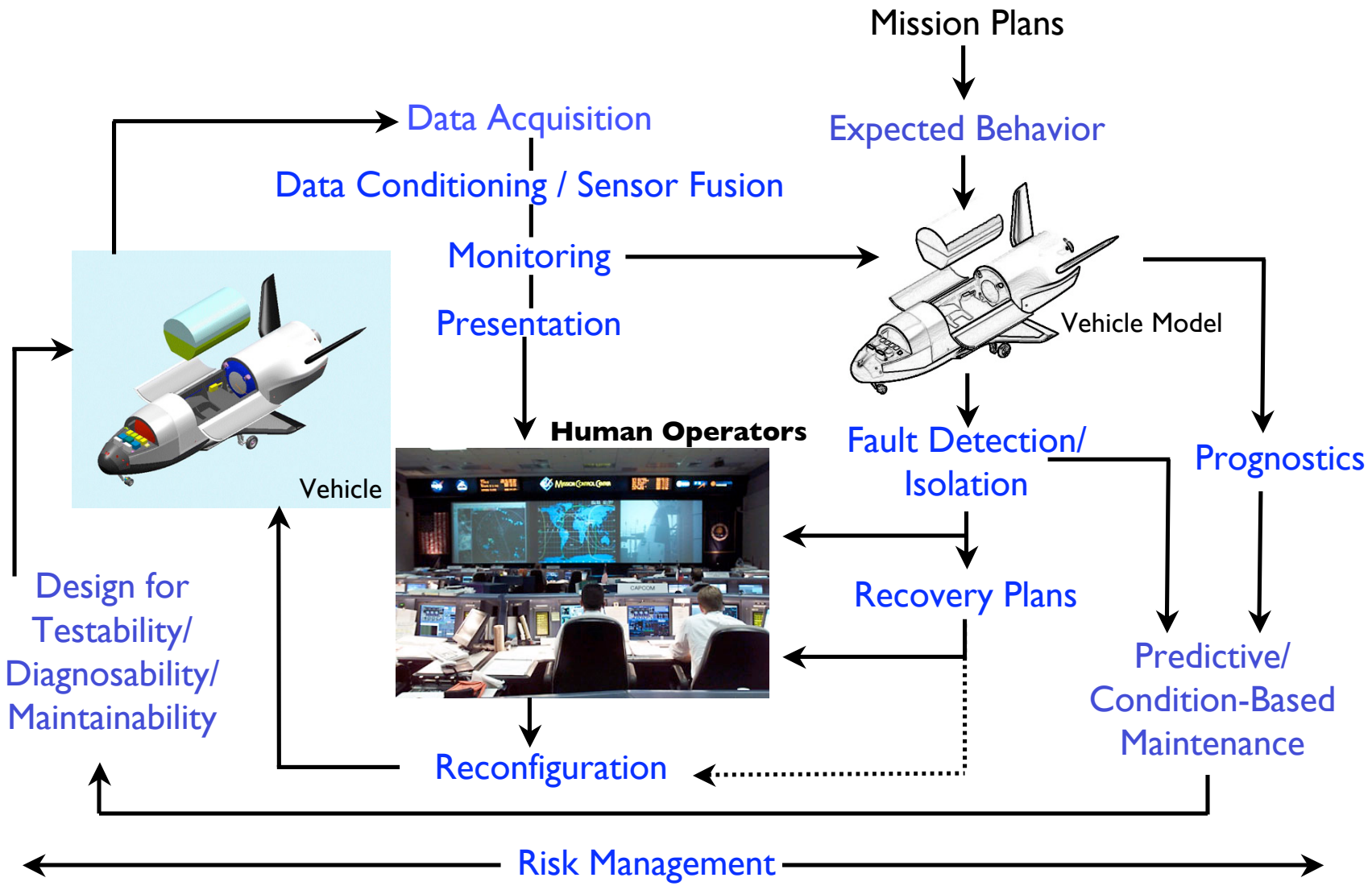
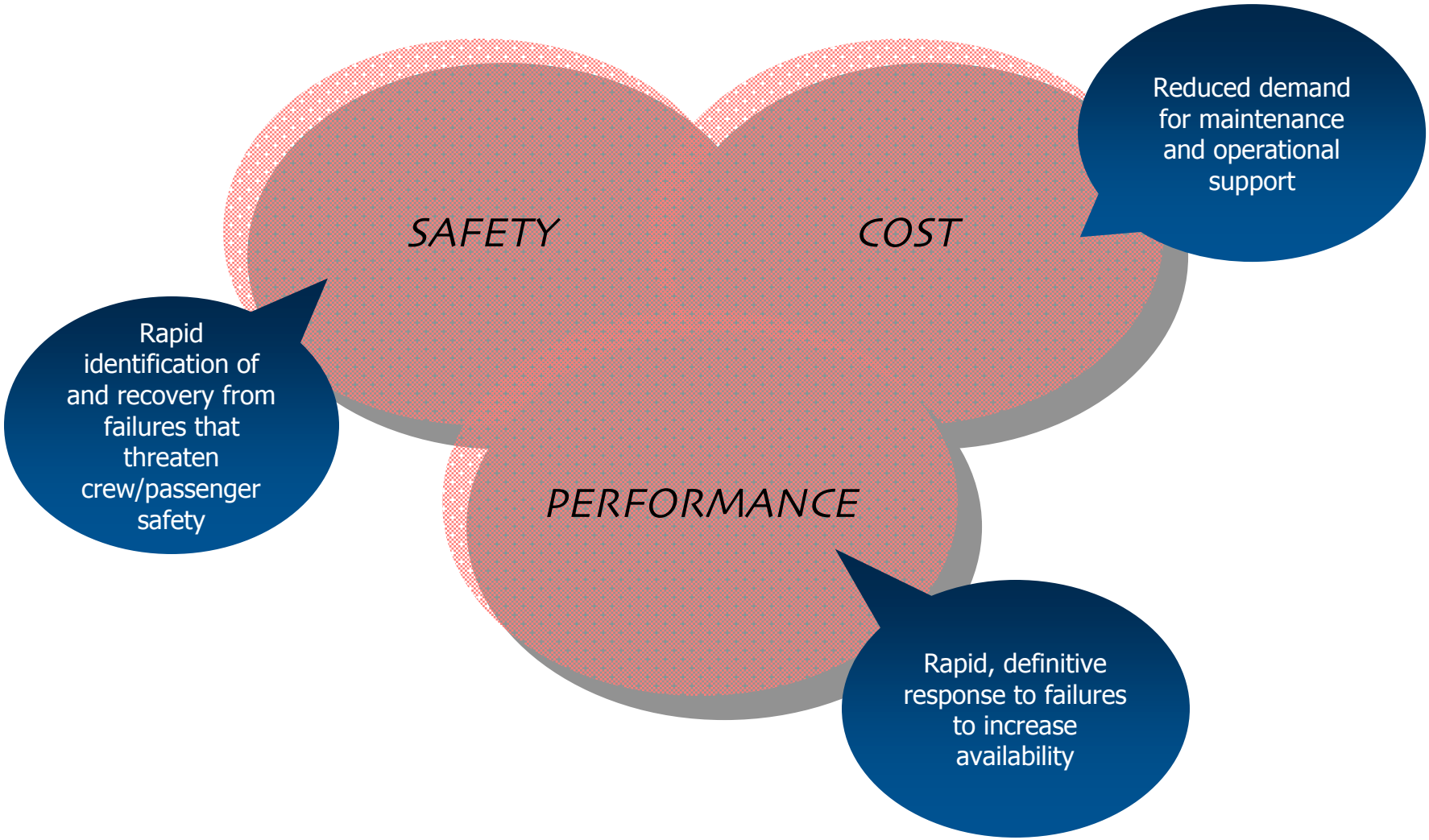
Outline

- Scope of ISHEM
- Where Are We Today?
- Paradigm Shifts
- Challenges and Recommendations
- Conclusions

Scope of ISHEM



Figures of Merit for ISHEM



A Historical Perspective …

(*Autonomous Mission Management circa 1968*)

- In year 2001, HAL 9000 was expected to:
  - –Break the moment-to-moment link to ground ops.
    - On-board Command and Control, System Monitoring
  - –Take Care of the Spacecraft.
    - Repair and Recovery, Systems Health
  - –Enable the Crew to focus on Exploration.
    - Activity Planning and Scheduling

HAL was not a complete success, but at least it was certified for human spaceflight!

Where are we today?

- Steady progress with major technical elements (e.g., prognostics, diagnostics, design, data analysis).
- Increased recognition and acceptance as a discipline of its own.
- Baselined in most major aerospace development programs.
- Proving return-on-investment is still a challenge.

State-of-the-Practice - 2005

Boeing 777: Sophisticated diagnostics and built-in-tests integrated with maintenance operations

F-35: Prognostics and Autonomic Logistics

Advanced Health Management System for the Space Shuttle Main Engine

FOMs for State-of-the-Practice

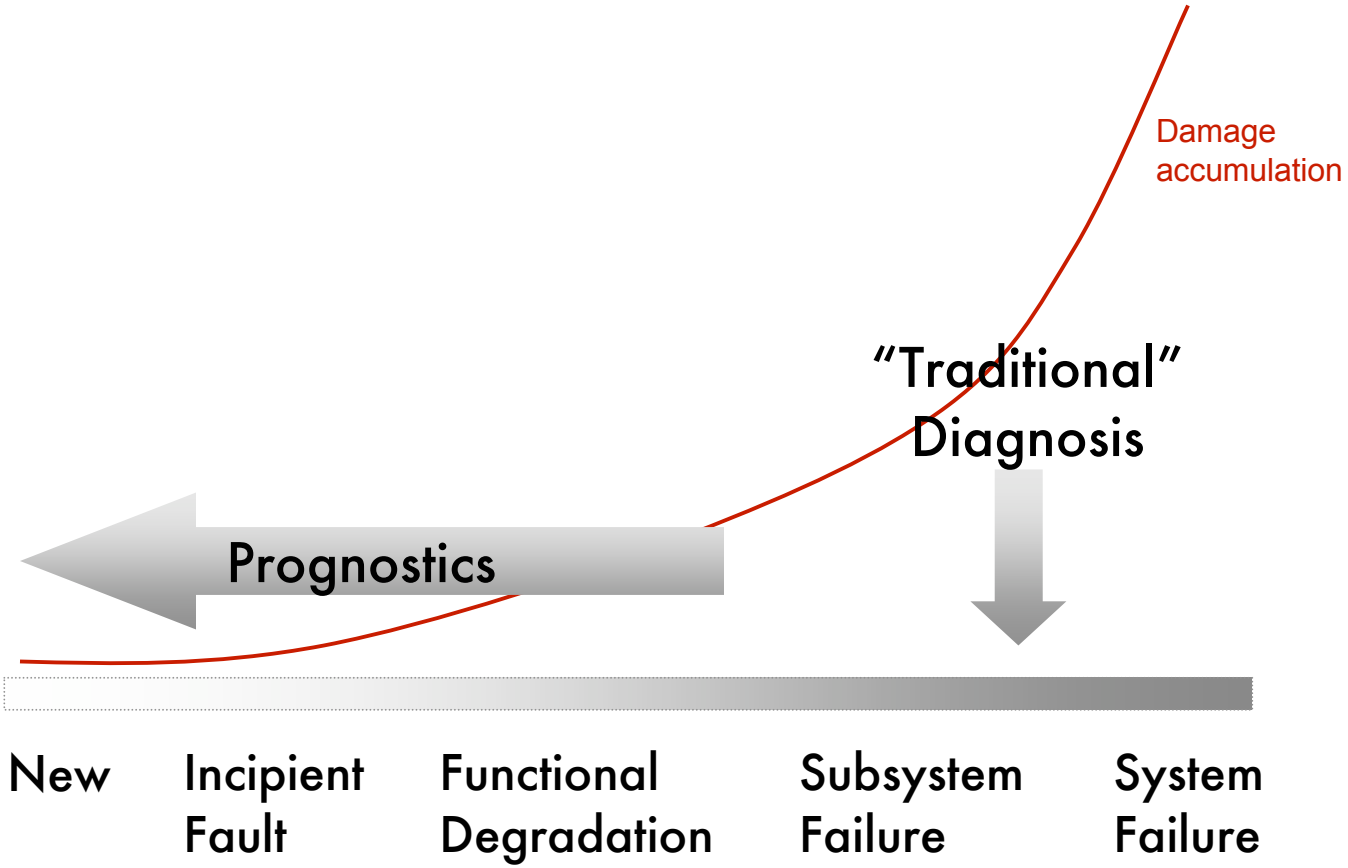
PERFORMANCE and COST

COST and PERFORMANCE

SAFETY

Paradigm Shifts

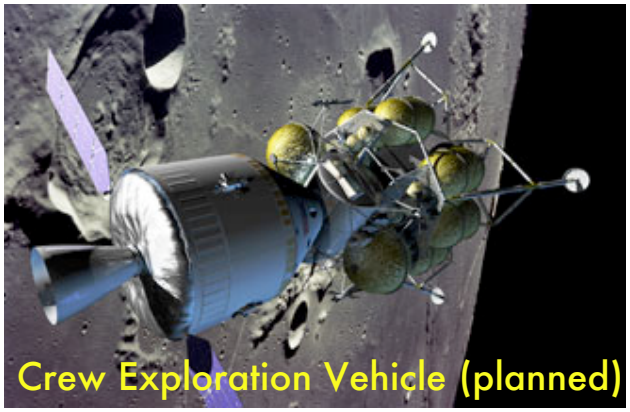
Prognostics and Physics of Failure



Paradigm Shifts

Health Management Incorporated into Design

Fault and prognostic coverage requirements



Efficient ground processing; remote health assessment during long-during unmanned operations

Abort / crew escape decision making

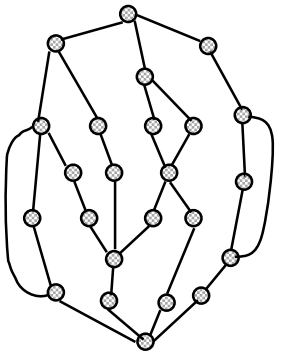
Challenges

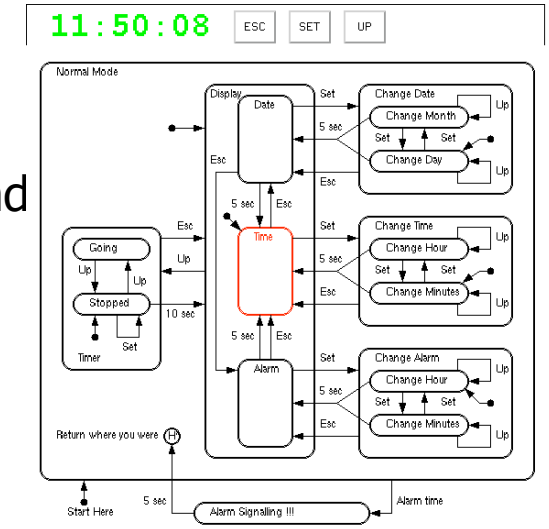
Sensor Reliability and Validation

- Often times, sensors are not as reliable as the systems they monitor
  - Failures; noise; drift; unknown response to novel conditions
- Lack of sensor validation may cause mishaps or catastrophic failures:
  - Mars Polar Lander touchdown sensor transient
  - Delta IV Heavy propellant cavitation
- The most reliable solution is independent confirmation of sensor readings (e.g., robust state estimation)

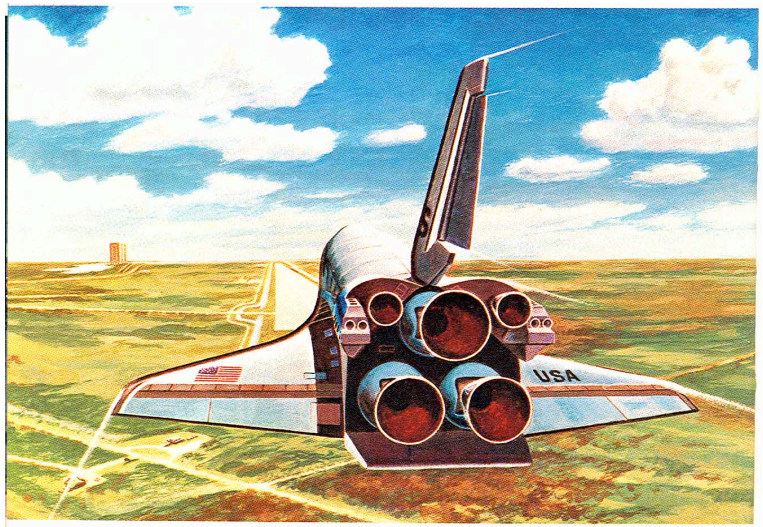
Challenges
Verification and Validation

- Traditional flight software certification methods require exhaustive testing:
  - Of all nominal execution traces (all possible branches) of the software
  - In response to all input commands and allowable sensor values
  - Of known failure modes
- Simply not possible for health management systems of reasonable complexity
  - More R&D needed in automated verification and validation
  - Flight certification methods need to accommodate the unique needs of health management systems.





Challenges
Inflated Expectations



GROUND TURNAROUND

The Space Shuttle Orbiter is designed for a 2-week ground turnaround, from landing to relaunch. About 160 hours of actual work will be required.
(from a book published in 1976)

- Lack of credible cost or performance models
- Inability to predict the benefits of HM investments
- Inability to accurately estimate the cost of developing and maintaining the HM capability

Challenges

Impact of Organizations

- A consistent, coherent health management implementation needs to managed across the entire system.
- Distributing HM responsibility to subsystems creates information stovepipes
  - Interface issues (e.g., limited understanding of assumptions and design constraints)
  - Restricted situational awareness
  - Difficulty in understanding subsystem couplings that lead to failures
  - Responsibility ≠ authority
- "A fielded system is a reflection of the organization." (Col. Damian Bianca, US Army SMDC)

Summary and Conclusions

- Over the last ten years, health management has become standard practice across the aerospace industry
- Technologies used for HM are relatively mature and stable
- Field implementations are widely varied in scope and extent due to multiple figures-of-merit
- Organizational issues (e.g., implementation responsibility and authority) are key to success
- Accurate cost and performance models are required to turn ISHEM from an art form to a scientific endeavor.